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(54) BOWED FIN FOR HEAT EXCHANGER

(57) A heat exchanger includes a plurality of first fluid passages 45 configured to receive a first stream and a plurality of second fluid passages 43 each formed between two first fluid passages. Each first fluid passage includes a first plate and a second plate 46 parallel to the first plate. The first plate and second plate are connected by two closure bars. The first fluid passage also includes a fin pack 60 having a plurality of fins connected to the first and second plate, and configured for the first stream to flow around the fins. The fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin. Each second fluid passage is configured to receive a second stream and is configured to allow heat to indirectly exchange between the first stream and the second stream.

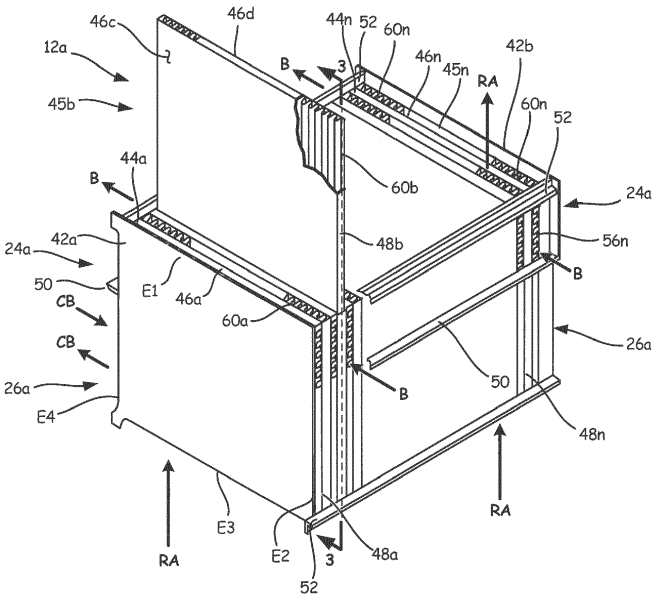


FIG. 2

EP 3 045 852 A1

Description

BACKGROUND

[0001] Heat exchangers are devices configured to allow for heat to be exchanged between two or more fluids or reservoirs. Indirect heat exchangers allow for heat to be exchanged between fluids indirectly, or without contact between the fluids. To enable efficient heat transfer, many variables of indirect heat exchangers are manipulated to obtain optimum heat transfer. Variables of heat transfer efficiency such as the material of the heat exchanger, the heat exchanger's shape and size, and the flow rates and pressures of the fluids are all manipulated to optimize heat exchanger efficiency.

[0002] One way to increase heat exchanger efficiency is through the use of fins. Thermally efficient fins are often thin in one direction and frequently occurring in order to increase heat transfer while minimizing pressure drop. Thermally efficient heat exchangers are often composed of copper, aluminum, or a combination thereof, because these materials are good thermal conductors. More recently, many industries have begun using heat exchangers formed of only aluminum to save weight and cost, as aluminum is both less expensive and lighter than copper.

[0003] In an effort to increase thermal efficiency and decrease cost and weight, heat exchangers have become much more lightweight and often less robust. Though increasing heat exchanger thermal efficiency is desirable, premature component failure is costly.

SUMMARY

[0004] In an embodiment, a heat exchanger includes a plurality of first fluid passages configured to receive a first stream and a plurality of second fluid passages each formed between two first fluid passages. Each first fluid passage includes a first plate and a second plate parallel to the first plate. The first plate and second plate are connected by two closure bars. The first fluid passage also includes a fin pack having a plurality of fins connected to the first and second plate, and configured for the first stream to flow around the fins. The fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin. Each second fluid passage is configured to receive a second stream and is configured to allow heat to indirectly exchange between the first stream and the second stream.

[0005] In another embodiment, an environmental control system includes a heat exchanger, a gas turbine bleed source for providing a first stream to the heat exchanger, at least one ram air fan for providing a second stream to the heat exchanger, and an air cycle machine for receiving the first stream from the heat exchanger. Each heat exchanger includes a plurality of first fluid passages configured to receive a first stream and a plurality of second fluid passages each formed between two first fluid passages. Each first fluid passage includes a first plate and a second plate parallel to the first plate. The first plate and second plate are connected by two closure bars. The first fluid passage also includes a fin pack having a plurality of fins connected to the first and second plate, and configured for the first stream to flow around the fins. The fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin. Each second fluid passage is configured to receive a second stream and is configured to allow heat to indirectly exchange between the first stream and the second stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006]

FIG. 1 is a schematic view illustrating an embodiment of an aircraft environmental control system including a dual heat exchanger.

FIG. 2 is a partially exploded isometric view of a heat exchanger.

FIG. 3 is a close-up, partially exploded isometric view of a working fluid passage of the heat exchanger of FIG. 2.

FIGS. 4A and 4B are cross-sectional views of a portion of a bleed flow path of the heat exchanger of FIG. 2.

FIG. 5 is a close-up, partially exploded isometric view of another embodiment of a working fluid passage.

DETAILED DESCRIPTION

[0007] FIG. 1 is a schematic view illustrating an embodiment of aircraft environmental control system 10 including dual heat exchanger 12, gas turbine engine 13, air cycle machine 14, ram air inlet duct 16, ram air outlet duct 18, ram air fan 20, and ram air fan shaft 22. Dual heat exchanger 12 includes primary heat exchanger 24, and secondary heat exchanger 26. Aircraft environmental control system 10 also includes aspirator 28, bleed inlet duct 30, bleed primary outlet duct 34, secondary inlet duct 36, secondary outlet duct 38, and conditioned process outlet duct 40. Also illustrated in FIG. are bleed stream B, ram air RA, and process air stream P.

[0008] Dual heat exchanger 12 is shown as one heat exchanger; however, dual heat exchanger 12 may comprise two heat exchangers, 12a and 12b (not numbered in FIG. 1), where dual heat exchanger 12a includes primary heat exchanger 24a and secondary heat exchanger 26a, and dual heat exchanger 12b includes primary heat exchanger 24b and secondary heat exchanger 26b (also not shown in FIG. 1).

[0009] In the ram air system of aircraft environmental control system 10, ram air inlet duct 16 connects to the inlet of dual heat exchanger 12, which is the inlet of sec-

ondary heat exchangers 26. The outlet of secondary heat exchangers 26 connects to the inlet of primary heat exchanger 24. The outlet of primary heat exchanger 24 connects to the inlet of ram air outlet duct 18. Within ram air outlet duct 18 is ram air fan 20. Ram air fan 20 is connected to ram air fan shaft 22, which connects to a component within air cycle machine 14, such as a compressor and turbine (not shown). Aspirator 28 is mounted within ram air inlet duct 16 near the inlet of secondary heat exchanger 26.

[0010] In the bleed air system of aircraft environmental control system 10, bleed inlet duct 30 connects to the inlet of primary heat exchanger 24. Bleed inlet duct 30 also connects to bleed balancing duct 32 upstream of its connection to primary heat exchanger 24. Bleed primary outlet duct 34 connects to the bleed air discharge of primary heat exchanger 24. Bleed primary outlet duct 34 connects to an inlet of air cycle machine 14. Connected to an outlet of air cycle machine is secondary inlet duct 36. Downstream, secondary inlet duct 36 also connects to the inlet of secondary heat exchanger 26. The outlet of secondary heat exchanger 26 is connected to secondary outlet duct 38, which also connects to an inlet of air cycle machine 14. Conditioned process air outlet 40 connects to an outlet of air cycle machine 14.

[0011] In this embodiment, fan 20 is driven by shaft 22, which is driven by compressors and turbines (not shown) within air cycle machine 14. Fan 20 draws ram air RA into ram air inlet duct 16. Ram air RA is sprayed with a liquid and vapor mixture by aspirator 28. The liquid of the mixture evaporates into ram air RA, lowering the temperature of ram air RA. Ram air RA then travels to secondary heat exchanger 26. There, ram air RA will be heated up by process fluids traveling from secondary inlet duct 36, through secondary heat exchanger 26, to secondary outlet duct 38.

[0012] After traveling through secondary heat exchanger 26, ram air RA will exit secondary heat exchanger 26 and enter primary heat exchanger 24. In primary heat exchanger 24 ram air RA will be further heated by bleed air entering the heat exchanger from bleed inlet duct 30. Following the heat exchanges, ram air RA travels through ram air fan 20 and is propelled through ram air outlet duct 18 and is then exhausted overboard from the aircraft. Though primary heat exchanger 24 and secondary heat exchanger 26 are shown in a parallel configuration, a series configuration may be used in alternative embodiments.

[0013] Bleed stream B (process air), which is supplied by a component of gas turbine engine 13, such as a compressor, enters the inlet of bleed inlet duct 30 and travels through primary heat exchanger 24. In primary heat exchanger 24, the process air is cooled by ram air RA passing through primary heat exchanger 24. The process air then exits primary heat exchanger 24 and travels through primary outlet 34, before entering air cycle machine 14 where it will encounter a process component, such as a compressor. Following being subjected to at least one process, the process air can travel to secondary heat exchanger 26 by way of secondary inlet duct 36. The process air is then cooled by ram air RA through secondary heat exchanger 26, and enters air cycle machine 14. Following its entry into air cycle machine 14, the process air may be subjected to another process component such as a condenser or water collector. Then, the process air stream P may reenter the turbine or another process component of air cycle machine 14, or may be exhausted from air cycle machine 14 via conditioned process outlet duct 40. Thereafter, process air stream P may be sent to various components within the aircraft to perform heating or cooling functions. Additionally, process air stream P may be recirculated to any of the locations previously mentioned.

[0014] FIG. 2 is a partially exploded isometric view of dual heat exchanger 12a, which includes primary heat exchanger 24a and secondary heat exchanger 26a. Dual heat exchanger 12a includes end sheets 42a and 42b, working passages 43a-43n, bleed closure bars 44a-44n, cooling passages 45a-45n, parting sheets 46a-46n, ram closure bars 48a-48n, core bands 50, core framing 52, primary fin packs 56a-56n, and cold fin packs 60a-60n. Also illustrated in FIG. 2 are bleed stream B, conditioned bleed stream CB, and ram air RA. Further illustrated in FIG. 2 are ends E1, E2, E3, and E4. Included in dual heat exchanger 12a, but not shown are secondary hot fin packs.

[0015] Cold fin packs 60a-60n are disposed in cooling fluid passages 45a-45n, between every other set of parting sheets 46a-46n. For example, cold fin pack 60b is disposed between parting sheets 46c and 46d, but not between parting sheets 46b and 46c. Disposed between parting sheets 46b and 46c in working fluid passage 43b are primary hot fin pack 56b and secondary hot fin packs (not shown), where primary hot fin pack 56b is separated from the secondary hot fin packs (not shown).

[0016] Parting sheets 46a-46n are parallel and consistently spaced between end sheet 42a and 42b. Parting sheets 46a-46n are also parallel to end sheets 42a and 42b. Parting sheets 46a-46n are connected to bleed closure bars 44a-44n and ram closure bars 48a-48n. Ram closure bars 48a-48n connect parting sheets 46a-46n at two ends opposite from each other to form cooling passages 45a-45n. For example, ram closure bar 48b connects parting sheets 46c and 46d and encloses cold fin pack 60b, at end E2. Another ram closure bar 48b connects parting sheets 46c and 46d at end E4 (not shown) to create cooling passage 45b. Similarly, bleed closure bar 44b connects parting sheets 46b and 46c, which surround primary fin pack 56b, at end E1. Another bleed closure bar 44a connects parting sheets 46b and 46c at end E3 (not shown) to create working passage 43 a.

[0017] Core framing 52 is connected to end sheets 42a and 42b and contacts the sides of parting sheets 46a-46n, bleed closure bars 44a-44n, and ram closure bars 48a-48n. Core band 50 is located on ends E2 and E4 of dual heat exchanger 12a. Core band 50 contacts the

sides of parting sheets 46a-46n, and bleed closure bars 44a-44n, and ram closure bars 48a-48n. Further, core band 50 can be welded, or otherwise secured, to ram closure bars 48a-48n. For example, core bands 50 can be welded to dual heat exchanger 12a following the brazing of heat exchanger 12a. Although two of core bands 50 are shown, more may be used. Core framing 52 and core band 50 secures the components of heat exchanger 12a.

[0018] Dual heat exchanger 12a and all of its components are composed of aluminum. This allows dual heat exchanger 12a to be brazed together as a single assembly in an oven brazing process. However, other methods of securing and sealing the components, such as tack-welding and caulking, or fastening may be used. Also, heat exchangers of other materials such as copper or steel can be used.

[0019] Working passages 43a-43n contain both primary fin packs 56a-56n and secondary hot fin packs (not shown). The portion of working passages 43a-43n which contain primary fin packs 56a-56n, create primary flow paths for bleed air to travel through the process or working fluid side of primary heat exchanger 24a within dual heat exchanger 12a. In this embodiment, bleed air enters primary heat exchanger 24a at the surface of dual heat exchanger 12a between ends E1 and E3 and perpendicular to end E2. Bleed air exits primary heat exchanger 24a between ends E1 and E3 and perpendicular to end E4.

[0020] The portion of working passages 43a-43n containing secondary hot fin packs (not shown) create secondary flow paths for conditioned bleed stream CB to travel through the process or working fluid side of secondary heat exchanger 26a within dual heat exchanger 12a. In this embodiment, conditioned bleed stream CB enters secondary heat exchanger 26a on the surface of dual heat exchanger 12a between ends E1 and E3 and perpendicular to end E4. Conditioned bleed stream CB doubles back, turning its flow direction 180 degrees, and exits secondary heat exchanger 26a on the surface of dual heat exchanger 12a between ends E1 and E3 and perpendicular to end E4. While in dual heat exchanger 12a, bleed stream B and conditioned bleed stream CB are physically separated.

[0021] Also, cooling passages 45a-45n, which contain cold fin packs 60a-60n, create a flow path for ram air RA to travel through cooling fluid side of primary heat exchanger 24a and secondary heat exchanger 26a within dual heat exchanger 12a. In this embodiment, ram air RA enters secondary heat exchanger 26a on the surface of dual heat exchanger 12a between ends E2 and E4 and perpendicular to end E3. Ram air RA continues through secondary heat exchanger 26a and enters primary heat exchanger 24a without exiting its flow paths. Ram air RA then exits primary heat exchanger 24a between ends E2 and E4 and perpendicular to end E1.

[0022] In the operation of one embodiment, ram air RA enters cooling passages 45a-45n from ram air inlet duct 16 (of FIG. 1), bleed stream B enters the working fluid passages 43a-43n from bleed inlet duct 30a (of FIG. 1), and conditioned bleed stream CB enters the secondary flow path of working fluid passages 43a-43n from secondary inlet duct 36 (of FIG. 1). As conditioned bleed stream CB enters the secondary flow paths within secondary heat exchanger 26a it is cooled through indirect heat transfer by ram air RA that is traveling in adjacent ram air flow paths of secondary heat exchanger 26a. After being cooled by ram air RA, conditioned bleed stream CB exits secondary heat exchanger 26a. However, after cooling the conditioned bleed stream CB, ram air RA continues through cooling passages 45a-45n to primary heat exchanger 24a where cooling passages 45a-45n are adjacent to the portion of working passages 43a-43n containing bleed stream B. At this point, heat is indirectly exchanged between bleed stream B and ram air RA. This process cools bleed stream B as it travels through primary heat exchanger 24a, while heating ram air RA. Following this heat exchange, ram air RA exits primary heat exchanger 24a and enters ram air outlet duct 18a (of FIG. 1). Also, bleed stream B exits primary heat exchanger 24a and enters primary outlet duct 34 (of FIG. 1). The result is that bleed stream B has been cooled, conditioned bleed stream CB has been cooled, and ram air RA has been heated.

[0023] Within dual heat exchanger 12a, parting sheets 46a-46n transfer heat between the streams passing through the passages. For example parting sheet 26b transfers heat between bleed stream B and ram air RA. Within each passage, fin packs transfer heat from the streams to the parting sheets. For example, primary fin pack 56b, between parting sheets 46b and 46c, transfers heat from bleed stream B to parting sheet 46c. Then, from parting sheet 46c, heat can be transferred into ram air RA in cooling passage 45b between parting sheets 46c and 46d. Further, heat from parting sheet 46c can be transferred to cold fin pack 60b and then into ram air RA.

[0024] The fin packs increase the thermal efficiency of dual heat exchanger 12a by allowing more heat to be transferred between the streams flowing through the heat exchangers. Fins are typically comprised of a very thin, relative to the other fin dimensions, thickness of metal. This allows for the pressure drop of air flowing over the fins to be reduced while still increasing the effective heat transfer surface area of the heat exchanger. Thin fins are also desirable, because a smaller fin thickness allows for more fins to fit into a given space, further increasing surface area for heat transfer. In other words, the amount of heat exchanged is increased due to the increase in heat transfer surface area that fins provide, while the increase in pressure drop caused by the fins is maintained at a reasonable magnitude by using fins having a small cross-sectional area.

[0025] When fins are thin and are subjected to thermal cycling, a fin's fatigue stress may be reached more quickly than desired. Modification of the profile of a fin to in-

crease the fin's ability to withstand thermal cycling increases the life of the heat exchanger. This is further discussed below.

[0026] FIG. 3 is a close-up partially exploded isometric view of cooling passage 45b, which includes closure bar 48b, parting sheets 46c and 46d, and cold fin pack 60b. Cold fin pack 60b includes fins F, which include bowed fin portion 62 and 64 and fin base portions 66 and 68. Also shown in FIG. 3 are ends E1 and E2 and ram air stream RA.

[0027] Cold fin pack 60b is comprised of several of fins F between ram air closure bars 48b and span between ends E2 and E4. Bowed fin portion 62 and 64 and fin base portions 66 and 68 extend between ends E1 and E3 in a consistent profile, meaning these portions do not change shape between ends E1 and E3. This is also known as a flat fin type.

[0028] Bowed fin portion 62 is bowed in shape between parting sheets 46c and 46d (which are flat), and connects at its end near parting sheet 46d to fin base portion 68. Bowed fin portion 62 connects at its other end near parting sheet 46c to fin base portion 66. Connected to the other end of fin base portion 66 is bowed fin portion 64, which connects to another fin base portion 68. All of fins F have the same portions, creating a repeating fin profile when viewed from end E1, which repeats consistently between bleed closure bars 48b.

[0029] Cold fin pack 60b and parting sheets 46c and 46d connect to closure bar 48b at end E2 of cooling passage 45b. Parting sheets 46c and 46d mate to fin portions 66 and 68, respectively. Cold fin pack 60b and parting sheets 46b and 46d connect to the other closure bar 48b at end E4 of cooling passage 45b (not shown). This encloses cold fin pack 60b on all but two surfaces. The open surfaces of cold fin pack 60b are at ends E1 and E3.

[0030] These surfaces are open to allow ram air stream RA to pass through cooling passage 45b and heat exchanger 24a as described above. Further, ram air stream RA passes over all exposed surfaces of cold fin pack 60b, as shown in FIG. 3. Though only cooling passage 45b is shown, similar fin patterns may be used for any working or cooling passage of heat exchanger 12a.

[0031] FIGS. 4A and 4B are discussed concurrently to more accurately convey the operation of the illustrated components. FIG. 4A is a cross-sectional view of a portion of a cooling flow path of primary heat exchanger 24a. FIG. 4A illustrates cold fin pack 60b in a relative low temperature state. This may be when cold fin pack 60b is not in operation and exposed to ambient conditions of -100 to 120 degrees Fahrenheit (-73C to 49C), or during operation when exposed to similar temperatures. FIG. 4B is the same cross-sectional view of cold fin pack 60b' within primary heat exchangers, but FIG. 4B illustrates cold fin pack 60b' in relative high temperature state. This may be when cold fin pack 60b' is exposed to conditions similar to that of operational temperatures of up to (or over) 1000 degrees Fahrenheit (538C) when steel type materials are used, or temperatures of up to (or over) 500 degrees Fahrenheit (26C) when aluminum materials are used.

[0032] Illustrated in FIG 4A are cold fin pack 60b, which includes fins F. Fins F each includes bowed fin portions 62 and 64 and fin base portions 66 and 68. Also illustrated in FIG. 4A are fin height fh, fin thickness t, fin base width bw, fin width w, and parting sheet height ph. Illustrated in FIG 4B is cold fin pack 60b', which includes bowed fin portions 62' and 64' and fin base portions 66 and 68. Also illustrated in FIG. 4B are fin height fh, fin thickness t, fin base width bw, fin width w', parting sheet height ph, bowed fin portions 62 and 64 (shown in phantom in FIG. 4b), and fin base portions 66 and 68. The connection and operation of cold fin pack 60b is consistent with FIGS. 1-3. Cold fin pack 60b is disposed between parting sheets 46c and 46d, as described in FIG. 3.

[0033] The views illustrated in FIGS. 4A and 4B are cross-sectional, meaning cold fin packs 60b and 60b' extend into the cavity created by parting sheets 46c and 46d. Fin height fh, fin thickness t, fin base width bw, fin width w, fin width w', and parting sheet height ph are all dimensions. Fin height fh is the dimension of bowed fin portions 62 and 64 and 62'and 64'. Fin thickness t is the dimension of the thickness of fin F, otherwise known as the fin material thickness. Fin base width bw is the distance of fin base portions 66 and 68. Fin width w is the largest distance between bowed fin portions 62 and 64. Fin width w' is the largest distance between bowed fin portions 62' and 64'. Parting sheet height ph is the distance between parting sheets 46c and 46d. Parting sheet height ph is primarily determined by bleed closure bar 44b, which determines the spacing of parting sheets 46c and 46d for the fin packs disposed within each pair of parting sheets.

[0034] When cold fin pack 60b is exposed to a relatively low temperature, for example, 60 degrees Fahrenheit (15.6C), the cross-sectional profile of fin F will appear as it does in FIG. 4A. In this condition, bowed fin portions 62 and 64 are curved or bowed in opposite directions. This bowing provides fin width w and fin height fh, where fin width w is wider than fin base width bw, and where fin height fh is equal to parting plate height ph.

[0035] When cold fin pack 60b is exposed to operational temperatures, similar to when exposed to bleed air (through heat transfer), the temperatures seen may reach 500 degrees Fahrenheit (260C). At these temperatures the cross-sectional profile of the fin will appear as it does in FIG. 4B. In the condition of FIG. 4B, bowed fin portions 62' and 64' have a greater bow than bowed fin portions 62 and 64 (shown in phantom in FIG. 4B). This bowing provides a fin width w', but fin height fh remains constant, as fin height fh is constrained by parting sheets 46c and 46d (and therefore closure bar 48b). Fin width w' becomes larger than fin width w, due to thermal expansion of fins F. The thermal expansion is caused by the thermal load applied by the high temperatures of bleed air flowing over fins F. The bowing of fins F may not be uniform, as is shown in FIGS. 4A and 4B. Regard-

less, the result is fin F has a fatigue strength that is greater than an un-bowed fin, as described below in greater detail.

[0036] The improved fin design is obtained through specific manufacturing processes. To manufacture a bowed fin at the appropriate height, several processes may be used. In one embodiment, an effective process is to form a fin .001 to .005 inches (0.025 to 0.127 mm) above parting sheet height ph. Then, the fin may be spanked to match parting sheet height ph (or the closure bar height). Spanking is a process where a compressive force controllably alters the height of a component through pressure applied to plates on either side of the fin. Thereafter, the fin can be placed inside its heat exchanger so that it may be brazed into the heat exchanger. This results in, for example, cold fin pack 60b that have fins F having a height equivalent to parting sheet height ph and a bow in bowed fin portions 62 and 64, which allows for width w to increase to width w'.

[0037] After this manufacturing process cold fin pack 60b is configured so that if it were outside of parting sheets 46c and 46d, it would be allowed to straighten, or unbow and increase in fin height fh due to thermal expansion when exposed to a thermal load similar to the design conditions. The increase in fin height fh may be, for example between 0.0005 inches and 0.005 inches (0.0127 to 0.127 mm) when placed under the thermal load. Typically, the increase in fin height fh is small relative to the dimensions of the fin. For example, the fin height may be 0.5 inches (12.7 mm) and the increase in fin height may be 0.005 inches (0.127 mm).

[0038] When cold fin pack 60b is placed between parting sheets 46c and 46d it is not free to fully expand. In the prior art, when a fin pack is under thermal load and not free to expand, the thermal expansion causes both stress and strain on the fin pack (where strain is a measurement of deformation experienced by a material, and stress is a measurement of potentially deforming force to cross-sectional area). Both thermally induced stress and strain of the fin pack can cause adverse effects to the fin pack. Specifically, cyclical stress caused by the thermal expansion and contraction discussed above can lead to cracking of fins within a heat exchanger when the fatigue strength or fatigue limit of the fin material is reached. This cracking quickly propagates in subsequent thermal cycles, and ultimately leads to failure of the fins within the heat exchanger. This issue is particularly common where thin fins are used to increase thermal efficiency and decrease weight and cost, because thin fins are less able to withstand the thermally induced strains. Vibrations have been known to create or worsen these problems. These issues are prevalent in aircraft heat exchangers, which may use (relatively) thin fins, experience high thermal variance, are frequently cycled (due to starting and stopping of engines associated with flight), and frequently encounter vibrations.

[0039] The methods of this disclosure address these problems. Cold fin pack 60b helps to reduce this issue, because fins F have a bowed profile which allows cold fin pack 60b to absorb the stress and strain better than an unbowed fin. For example, cold fin pack 60b is placed in dual heat exchanger 12a in areas susceptible to thermal expansion and high deformation. For example, near the bleed inlet, the incoming bleed stream B temperature may be 1000 degrees Fahrenheit (538C) when steel type materials are used, or temperatures of up to (or over) 500 degrees Fahrenheit (26C) when aluminum materials are used. At this time of operation, ram air RA may have an inlet temperature ranging from -100 to 200 degrees Fahrenheit (-73C to 93C). Regardless, this is a large temperature difference between the cooling fluids (ram air RA) and the process or working fluid (bleed stream B). In this location, cold fin pack 60b will encounter this temperature range and may experience frequent expansion and contraction.

[0040] When cold fin pack 60b is between parting sheets 46c and 46d, cold fin pack 60b will not be free to expand to its full height when exposed to bleed stream B at a high temperatures. Instead, while between parting sheets 46c and 46d, the bowed fin will change shape as shown in FIG. 4B, increasing from width w to width w'. This flexing of fins F are designed to withstand stresses and strains created by the fin tensile load, by changing shape in a controlled and predetermined manner. The bowed configuration is analogous to a spring, in that it is capable of handling repetitive thermally induced loads without failing.

[0041] To obtain a fatigue strength of cold fin pack 60b even higher than that induced by the high operational temperature caused by bleed air, straight fins F may be used. Straight fins have a lower moment of inertia than wavy or corrugated fins, allowing straight fins to flex more easily. The use of a bowed straight fin provides the fins with significantly higher fatigue strength and reduces the stresses and strains on cold fin pack 60b. This allows for the heat exchanger to last for significantly more thermal or operational cycles, saving material cost, labor cost, and reducing risks associated with component failure during aviation flight.

[0042] In some embodiments, bowed fins may be used throughout dual heat exchanger 12a. In other embodiments, some fin packs may contain unbowed fins and some fin packs may contain bowed fins. For example, bowed fins may be strategically placed in dual heat exchanger 12a in areas that are most susceptible to thermal expansion induced fatigue stress failures, such as the fin packs most near the entrance of bleed air B into primary heat exchanger 24a where the largest thermal gradient between bleed air B and ram air RA will be exist within heat exchanger 12a. Then, a second type of fin that is not bowed, such as a fin type created by electrical discharge machining (EDM), can be used in all other locations of heat exchanger 24a. These fins are often optimized for thermal performance, whereas bowed fins are optimized to avoid failure. This strategy allows for bowed fins to be used sparingly, which can reduce the cost of

the heat exchanger as bowed fins require more or different steps of manufacturing, thus increasing their cost relative to unbowed fins.

[0043] Because use of bowed fins in only some areas is effective to increase the life of the heat exchanger, bowed fins may be replaced for other fin styles in existing heat exchangers in areas most susceptible to failure due to thermal loads and cycling. For example, bowed fins or fin packs may be substituted for fins or fin packs most near the entrance of bleed air in a heat exchanger already existing in an aircraft.

[0044] FIG. 5 is a close-up partially exploded isometric view of cooling passage 45b', which includes closure bar 48b, parting sheets 46c and 46d, and cold fin pack 60b. Cold fin pack 60b includes fins F. Each fin includes several of fin section f. Each fin section f includes bowed fin portion 62 and 64 and fin base portions 66 and 68. Also shown in FIG. 5 are ends E1 and E2 and ram air stream RA. Elements of FIG. 5 that are similar to elements of FIG. 3 are identified by similar character reference numbers.

[0045] Cold fin pack 60b is comprised of several fins F between bleed closure bars 48b. Fins F are connected to one another (as described below and above) and span between ends E1 and E2. Fin sections f are small in dimension relative to the dimension of fin F between ends E1 and E3. Each fin F includes several fin sections f, which include bowed fin portion 62 and 64 and fin base portions 66 and 68. Each fin section f is offset from adjacent fin sections f within its own fin F, and is offset from fin sections f of nearby fins F. This is also known as a serrated fin type. The remainder of the connections of cooling passage 45b' are consistent with FIG. 3.

[0046] As in cooling passage 45b, all but two surfaces of cooling passage 45b' are closed. The open surfaces of cooling passage 45b are at ends E1 and E3. These surfaces are open to allow ram air stream RA to pass through cooling passage 45b and heat exchanger 24a as described above. Further, ram air stream RA passes over all exposed surfaces of cold fin pack 60b, as shown in FIG. 3. However, unlike cooling passage 45b, ram air stream RA flowing through cold fin pack 60b of cooling passage 45b' will continuously split as it encounters staggered fin section f, specifically encountering bowed fin portions 62 and 64 as ram air stream stream RA passes through cooling passage 45b'. Though only cooling passage 45b' is shown, similar fin patterns may be used for any working or cooling passage.

[0047] Parting sheets 46a-46n are comprised of a thermally conductive material, such as aluminum, to allow for heat to indirectly transfer between the adjacent streams within dual heat exchanger 12a. Similarly, cold fin packs 60a-60n, primary fin packs 56a-56n, and secondary hot fin packs are comprised of a thermally conductive material, such as aluminum, to allow for heat to indirectly transfer between the adjacent streams within dual heat exchanger 12a. However, materials other than aluminum, such as copper, stainless steel, cupronickel, or any other thermally conductive materially may be used.

[0048] Dual heat exchanger 12a is shown as having two heat exchangers, primary heat exchanger 24a and secondary heat exchanger 26a; however, the present disclosure may apply to single heat exchangers. Additionally, dual heat exchanger 12a is shown having the flow direction of ram air RA being orthogonal to the flow direction of bleed stream B; however, the present disclosure may apply to heat exchangers having any relative flow directions. For example, the present disclosure may apply to heat exchangers arranged in a thermal counter flow arrangement, a thermal co-flow arrangement, or a thermal cross-flow arrangement. Similarly, the present disclosure may apply to heat exchangers with varying passes. For example, a single pass heat exchanger may be used; however, a multi-pass heat exchanger may also be used.

[0049] The bowing of fins may be applied to fins of many shapes. Straight fins, as shown in FIGS. 4A and 4B as well as serrated fins are examples of some shapes where bowing provides benefits.

[0050] Though the heat exchanger disclosed herein is described as mounting to a bleed system of an aircraft, any heat exchanger may make use of fin bowing to increase the life of the heat exchanger. For example, bowed fins may be used in an outdoor air to exhaust air heat exchanger in a home. Bowed fins may also be used in a cross-flow type heat exchanger in commercial, industrial, or process type HVAC applications.

[0051] Further, bowed fins may be applied to other types of heat exchangers aside from air-to-air heat exchangers. For example, bowed fins may be used on refrigerant to air, or water to air heat exchangers.

[0052] Although bowing is described in the methods of this disclosure, other shapes of the fin profile or cross-section may be used that increase the fatigue strength of the fin.

Discussion of Possible Embodiments

[0053] The following are non-exclusive descriptions of possible embodiments of the present invention.

[0054] A heat exchanger includes a plurality of first fluid passages configured to receive a first stream and a plurality of second fluid passages each formed between two first fluid passages. Each first fluid passage includes a first plate and a second plate parallel to the first plate. The first plate and second plate are connected by two closure bars. The first fluid passage also includes a fin pack having a plurality of fins connected to the first and second plate, and configured for the first stream to flow around the fins. The fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin. Each second fluid passage is configured to receive a second stream and is configured to allow heat to indirectly exchange be-

tween the first stream and the second stream.

[0055] The heat exchanger of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

[0056] The fin can include a plurality of first fin base portions parallel and adjacent to the first plate, a plurality of second fin base portions parallel and adjacent to the second plate, and a plurality of first and second bowed fin portions connected between the first and second fin base portions. The first and second bowed fin portions are oppositely bowed and are configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin.

[0057] The fins can extend from a first end of the first fluid passage to a second end of the first fluid passage between the first and second plates, and the profile of the fins can be consistent between the first and second end of the first fluid passage.

[0058] The first and second fin base portions and the first and second bowed fin portions can extend from a first end of the first fluid passage to a second end of the first fluid passage, and the portions can form a plurality of fin sections that are offset between the first and second end of the first fluid passage such that adjacent fin sections can be offset from each other moving from the first end of the first fluid passage to the second end of the first fluid passage.

[0059] The heat exchanger can be a dual heat exchanger having a primary and a secondary heat exchanger.

[0060] The primary heat exchanger can be configured to receive bleed air from a gas turbine engine and can be configured to receive ram air that has passed through the secondary heat exchanger.

[0061] The heat exchanger can include a second fin disposed in some of the fluid passages. The second fin can have a cross-sectional profile that is not bowed.

[0062] The fins can be only used in first fluid passages near local areas of the primary heat exchanger subject to a high thermal load and the second fin can be used throughout the remainder of the heat exchanger.

[0063] An environmental control system includes a heat exchanger, a gas turbine bleed source for providing a first stream to the heat exchanger, at least one ram air fan for providing a second stream to the heat exchanger, and an air cycle machine for receiving the first stream from the heat exchanger. Each heat exchanger includes a plurality of first fluid passages configured to receive a first stream and a plurality of second fluid passages each formed between two first fluid passages. Each first fluid passage includes a first plate and a second plate parallel to the first plate. The first plate and second plate are connected by two closure bars. The first fluid passage also includes a fin pack having a plurality of fins connected to the first and second plate, and configured for the first stream to flow around the fins. The fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin. Each second fluid passage is configured to receive a second stream and is configured to allow heat to indirectly exchange between the first stream and the second stream.

[0064] The system of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

[0065] The fin can include a plurality of first fin base portions parallel and adjacent to the first plate, a plurality of second fin base portions parallel and adjacent to the second plate, and a plurality of first and second bowed fin portions connected between the first and second fin base portions. The first and second bowed fin portions are oppositely bowed and are configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin.

[0066] The fins can extend from a first end of the first fluid passage to a second end of the first fluid passage between the first and second plates, and the profile of the fins can be consistent between the first and second end of the first fluid passage.

[0067] The first and second fin base portions and the first and second bowed fin portions can extend from a first end of the first fluid passage to a second end of the first fluid passage, and the portions can form a plurality of fin sections that are offset between the first and second end of the first fluid passage such that adjacent fin sections can be offset from each other moving from the first end of the first fluid passage to the second end of the first fluid passage.

[0068] The secondary heat exchanger can be configured to receive ram air from a ram air inlet, and discharge ram air into the primary heat exchanger, and the primary heat exchanger can be configured to receive bleed air from a gas turbine engine and discharge the bleed air into the air machine.

[0069] While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A heat exchanger comprising:

a plurality of first fluid passages (45a-45n) con-

figured to receive a first stream, each first fluid passage comprising:

a first plate (46c);
a second plate (46d) parallel to the first plate, wherein the first plate and second plate are connected by two closure bars (48);
a fin pack (60b) having a plurality of fins (F) connected to the first and second plate, and configured for the first stream to flow around the fins, wherein the fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin; and

a plurality of second fluid passages (43a-43n) each formed between two first fluid passages, wherein each second fluid passage is configured to receive a second stream, and wherein the second fluid passage is configured to allow heat to indirectly exchange between the first stream and the second stream.

2. The heat exchanger of claim 1, wherein the fin further comprises:

a plurality of first fin base portions (66, 68) parallel and adjacent to the first plate;
a plurality of second fin base portions parallel and adjacent to the second plate;
a plurality of first and second bowed fin portions (62, 64) connected between the first and second fin base portions, wherein the first and second bowed fin portions are oppositely bowed and are configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin.

3. The heat exchanger of claim 2, wherein each fin extends from a first end of the first fluid passage to a second end of the first fluid passage between the first and second plates, and where the profile of each fin is consistent between the first and second end of the first fluid passage.

4. The heat exchanger of claim 2, wherein the first and second fin base portions and first and second bowed fin portions extend from a first end of the first fluid passage to a second end of the first fluid passage, and wherein the portions form a plurality of fin sections that are offset between the first and second end of the first fluid passage such that adjacent fin sections are offset from each other moving from the first end of the first fluid passage to the second end of the first fluid passage.

5. The heat exchanger of claim 1, wherein each fin extends from a first end of the first fluid passage to a second end of the first fluid passage between the first and second plates, and wherein the profile of the fin is consistent between the first and second end of the fin.

6. The heat exchanger of claim 1, wherein the heat exchanger is a dual heat exchanger having a primary and a secondary heat exchanger.

7. The heat exchanger of claim 6, wherein the primary heat exchanger is configured to receive bleed air from a gas turbine engine and is configured to receive ram air that has passed through the secondary heat exchanger.

8. The heat exchanger of claim 7, wherein the heat exchanger further comprises a second fin disposed in some of the fluid passages, wherein the second fin has a cross-sectional profile that is not bowed.

9. The heat exchanger of claim 8, wherein the fins having a profile that is bowed are only used in first fluid passages near local areas of the primary heat exchanger subject to a high thermal load and the second fin is used throughout the remainder of the heat exchanger.

10. The heat exchanger of claim 9, wherein each fin extends from a first end of the first fluid passage to a second end of the first fluid passage, and wherein the profile of the fin is consistent between the first and second end of the first fluid passage.

11. An environmental control system comprising:

a heat exchanger comprising:

a plurality of first fluid passages configured to receive a first stream, each first fluid passage comprising:
a first plate;
a second plate parallel to the first plate, wherein the first plate and second plate are connected by two closure bars;
a fin pack having a plurality of fins connected to the first and second plate, and configured for the first stream to flow around the fins, wherein the fins have a cross-sectional profile that is bowed at non-operational temperatures and is configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin; and
a plurality of second fluid passages each formed between two first fluid passages, wherein each second fluid passage is configured to receive a second stream, and

wherein the second fluid passage is configured for heat to indirectly exchange between the first stream and the second stream.

a gas turbine bleed source for providing the first stream to the heat exchanger;
at least one ram air fan for providing the second stream to the heat exchanger; and
an air cycle machine for receiving the first stream from the heat exchanger.

12. The heat exchanger of claim 11, wherein the fin further comprises:

a plurality of first fin base portions parallel and adjacent to the first plate;
a plurality of second fin base portions parallel and adjacent to the second plate;
a plurality of first and second bowed fin portions connected between the first and second fin base portions, wherein the first and second bowed fin portions are oppositely bowed and are configured to flex under a thermal load without exceeding the tensile or fatigue strength of the fin.

13. The heat exchanger of claim 12, wherein each fin extends from a first end of the first fluid passage to a second end of the first fluid passage between the first and second plates, and where the profile of the fin is consistent between the first and second end of the first fluid passage.

14. The heat exchanger of claim 12, wherein the first and second fin base portions and first and second bowed fin portions extend from a first end of the first fluid passage to a second end of the first fluid passage, and wherein the portions form a plurality of fin sections that are offset between the first and second end of the first fluid passage such that adjacent fin sections are offset from each other moving from the first end of the first fluid passage to the second end of the first fluid passage.

15. The environmental control system of claim 14, wherein the secondary heat exchanger is configured to receive ram air from a ram air inlet, and discharge ram air into the primary heat exchanger, and wherein the primary heat exchanger is configured to receive bleed air from a gas turbine engine and discharge the bleed air into the air machine.

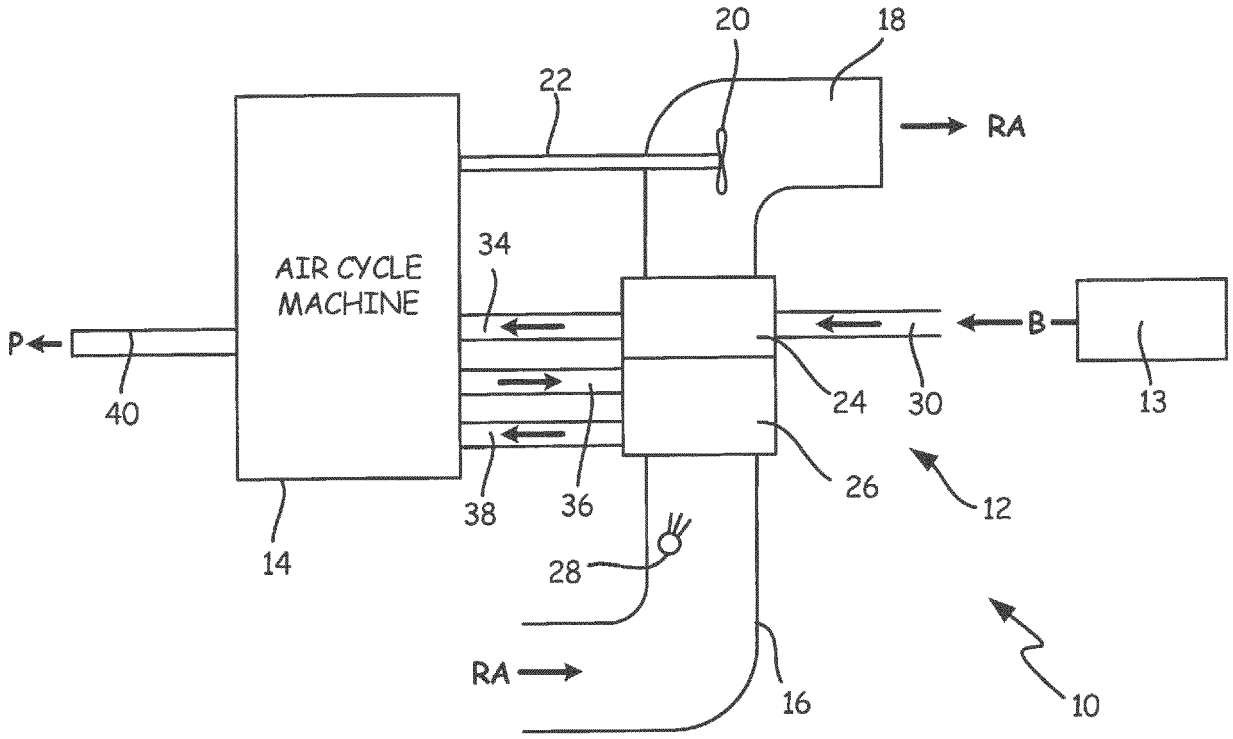

20
18
22
RA
AIR CYCLE
MACHINE
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P
B
40
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30
13
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12
14
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16
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FIG. 1

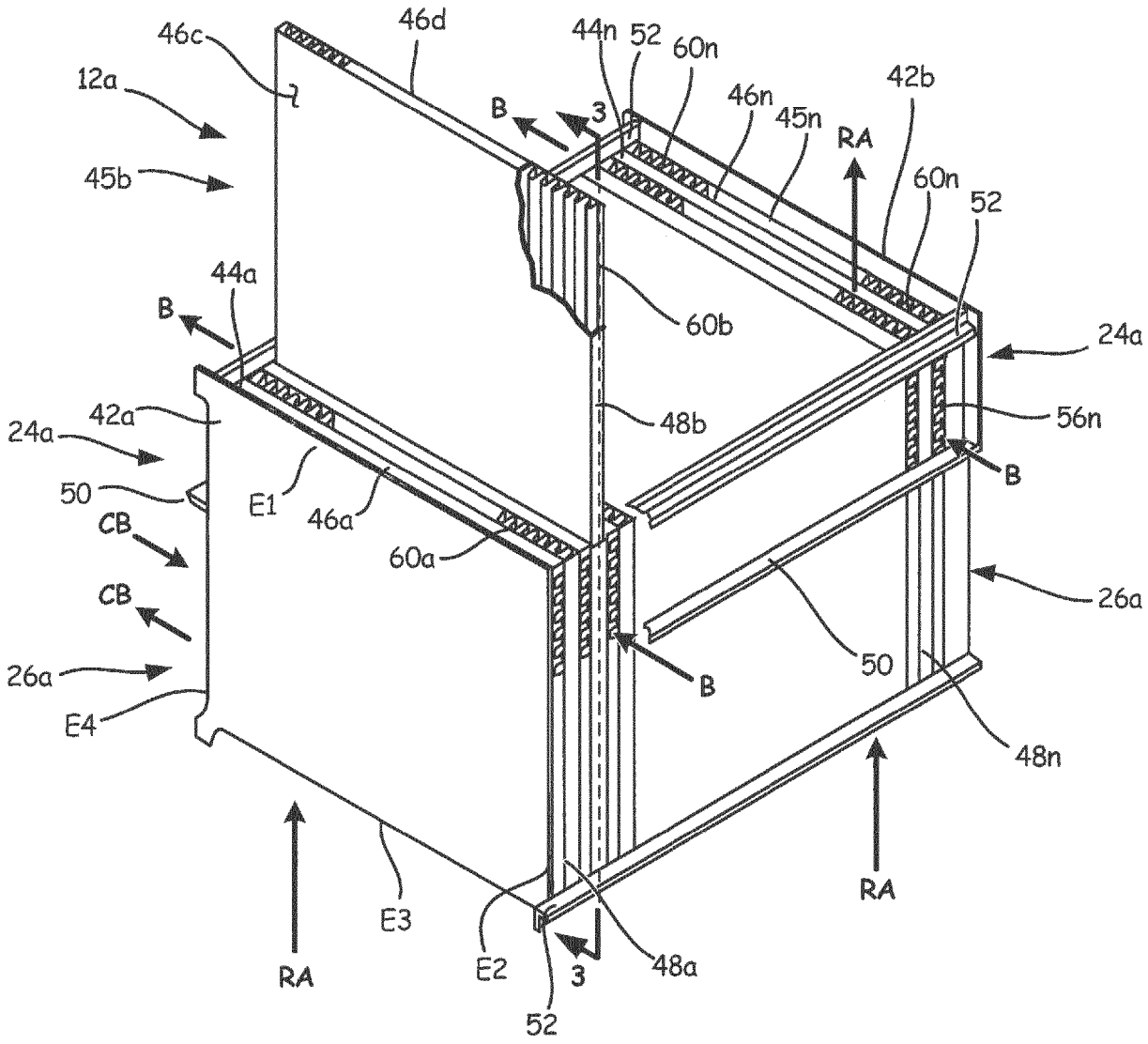

46c
46d
44n
52
60n
12a
B
3
46n
45n
RA
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45b
60n
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44a
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60b
24a
42a
48b
56n
24a
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FIG. 2

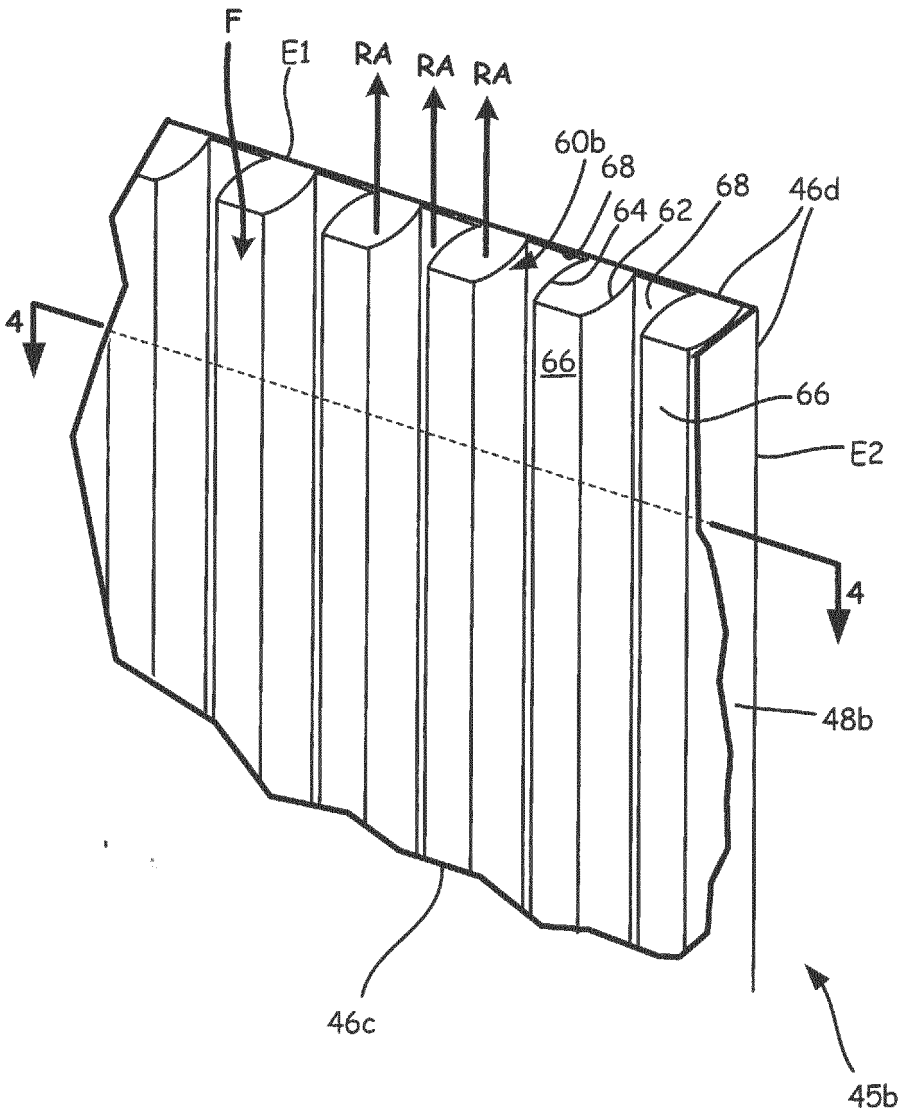


FIG. 3

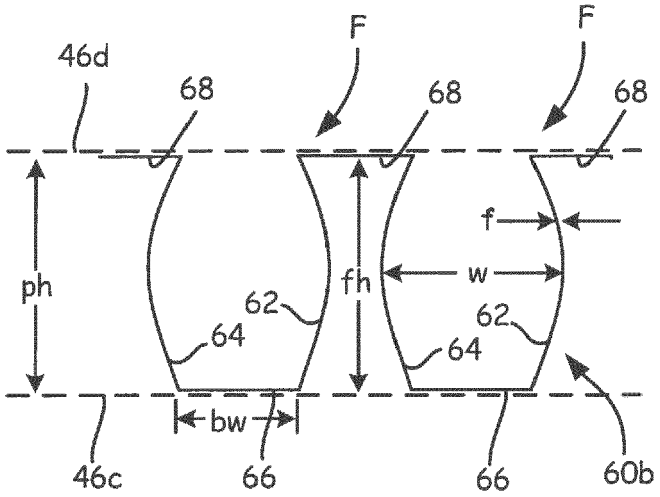

46d
68
F
68
F
68
ph
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f
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62
64
62
64
bw
46c
66
66
60b

FIG. 4A

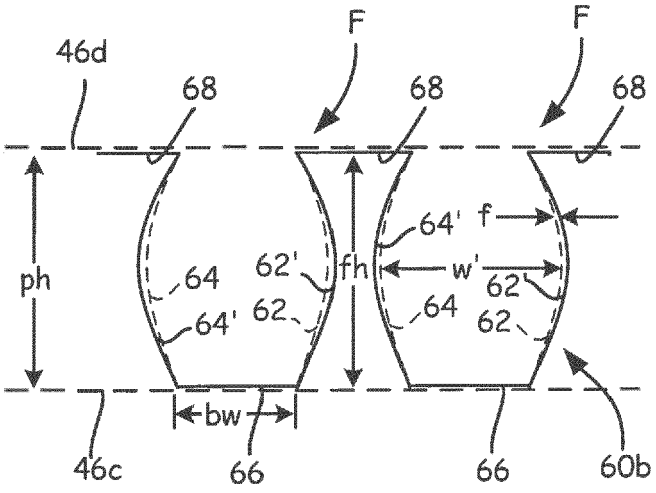

46d
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F
68
F
68
ph
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64'
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62'
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62
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46c
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66
60b

FIG. 4B

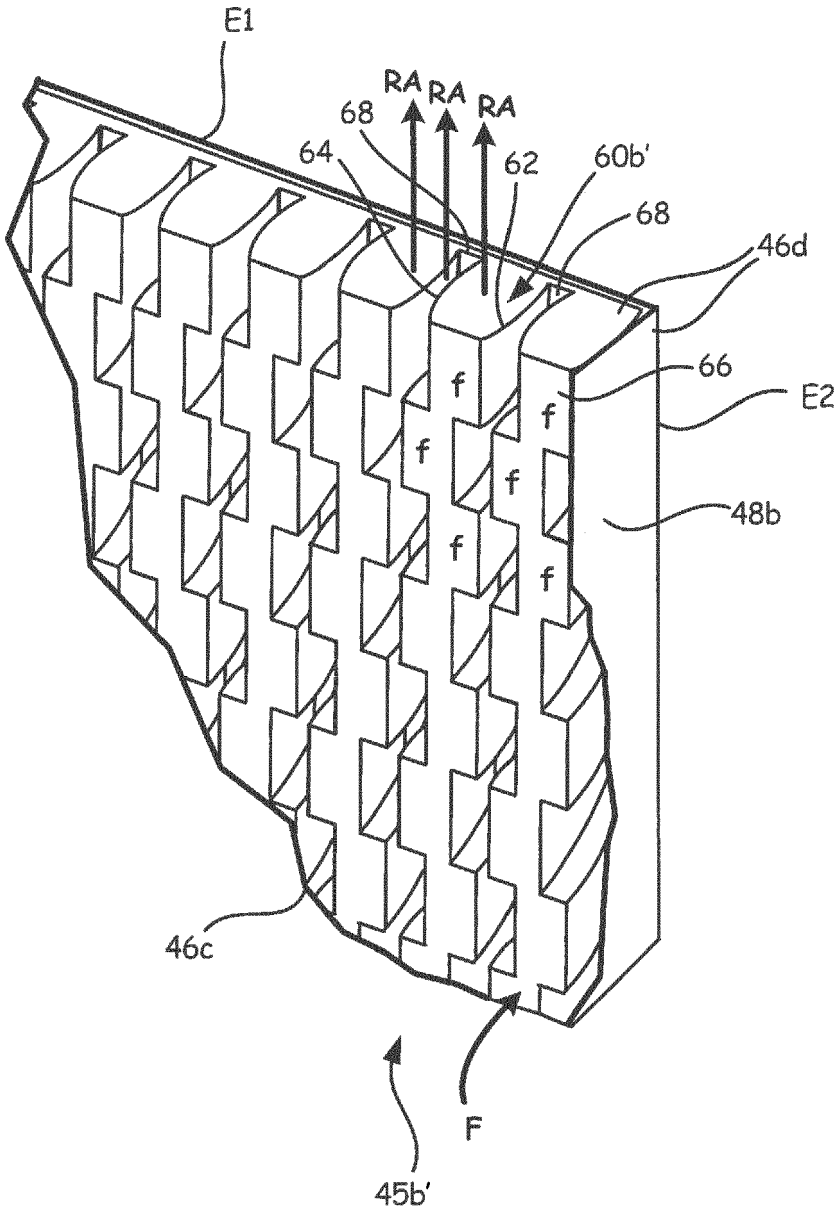


FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 1720

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 100 40 645 A1 (XCELLSIS GMBH [DE]) 13 June 2002 (2002-06-13) * figure 5 *	1-3,5-15	INV. F28F3/02 F28D9/00
X	US 5 564 496 A (BLUM BERNARD S [US] ET AL) 15 October 1996 (1996-10-15) * figure 2 *	1-3,5-15	
X	DE 20 2011 052186 U1 (AUTOKUEHLER GMBH & CO KG [DE]) 6 March 2013 (2013-03-06) * figures 3, 4 *	1-5	
X	FR 2 270 543 A2 (CHAUSSON USINES SA [FR]) 5 December 1975 (1975-12-05) * figure 7 *	1,5,6	
X	BE 750 222 A1 (FRANZ WAGNER & CO KG) 16 October 1970 (1970-10-16) * figure 2 *	1-3,5	
X	US 4 402 362 A (DUBROVSKY EVGENY V [SU]) 6 September 1983 (1983-09-06) * figure 3 *	1-3,5	TECHNICAL FIELDS SEARCHED (IPC) F28F F28D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	24 May 2016	Louchet, Nicolas

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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24-05-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 10040645 A1	13-06-2002	NONE	
US 5564496 A	15-10-1996	NONE	
DE 202011052186 U1	06-03-2013	DE 202011052186 U1	06-03-2013
		US 2013140010 A1	06-06-2013
FR 2270543 A2	05-12-1975	FR 2270543 A2	05-12-1975
		JP S5922153 B2	24-05-1984
		JP S50135661 A	28-10-1975
BE 750222 A1	16-10-1970	NONE	
US 4402362 A	06-09-1983	DE 2953738 A1	28-01-1982
		FR 2465982 A1	27-03-1981
		US 4402362 A	06-09-1983
		WO 8100148 A1	22-01-1981

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82